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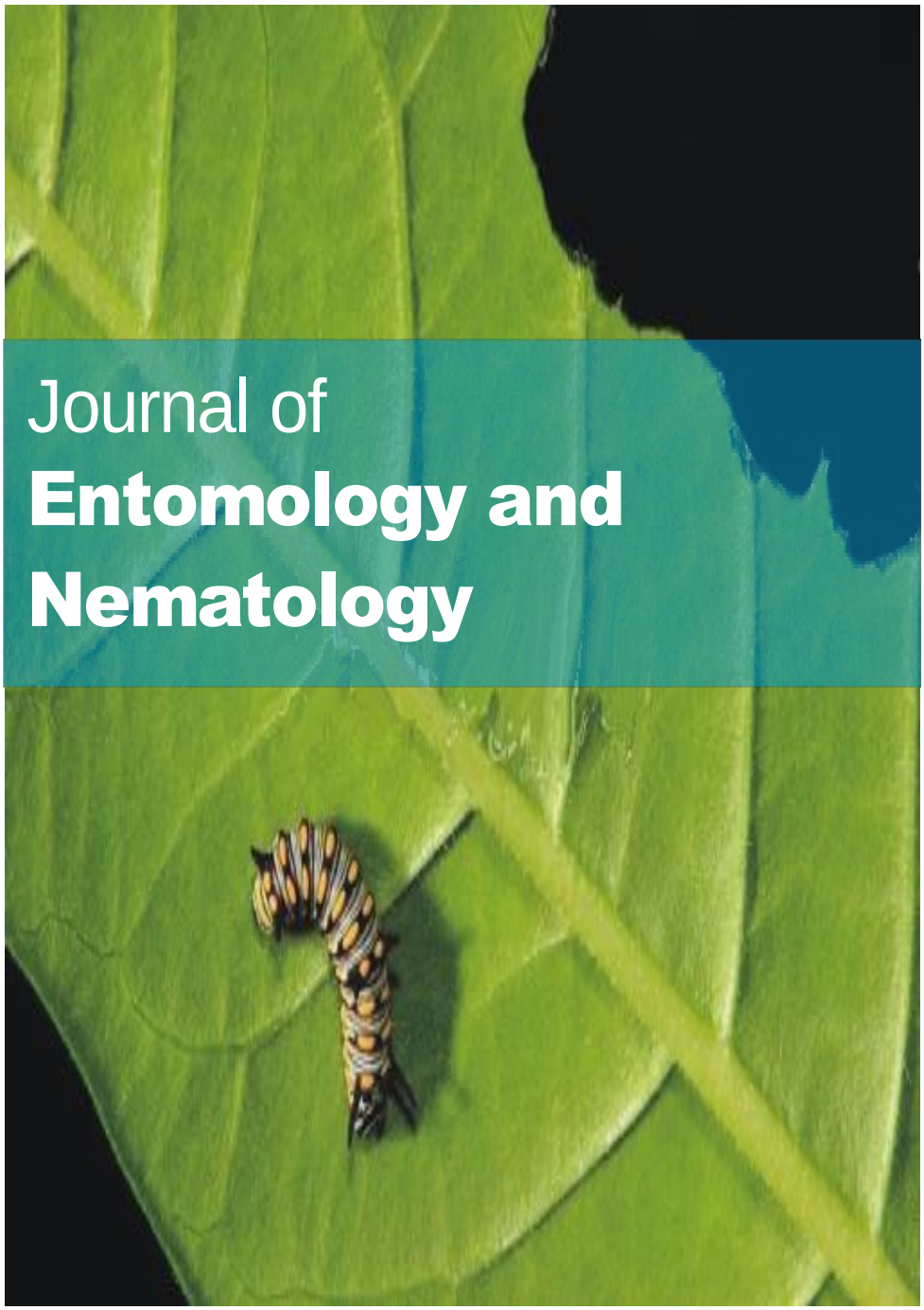

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Journal of Entomology and Nematology

Full Length Research Paper

Preliminary evaluation of the effect of three rates of ground leaves and fruits powders of *Myristica fragrans* on *Meloidogyne incognita* infecting sunflower *in vivo*

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Three rates of ground leaves and fruits powders of *Myristica fragrans* (5, 10 and 20 g/pot) were evaluated for their nematicidal effect against *M. incognita* infecting sunflower plants under greenhouse conditions. Results indicated that all tested applications significantly enhanced sunflower plant growth characters. Moreover, all tested treatments significantly gave better results with a significant correlation between the increase in the added dose and the improvement rate in the tested plant criteria and nematode parameters. The modest dose of leaves and fruits doses (10 g/pot) recorded the highest rates of improvement with values of 88.5 and 63.5; 88.9 and 75.0; 141 and 133.3% respectively for plant length, total plant wet weight and shoot dry weight. On the other hand, the highest rate of ground leaves and fruits powders of *M. fragrans* (20 g /pot) recorded the highest reduction in tested nematode criteria with values of 80.0 and 75.9% for final nematode reproduction and stated the lowest nematode reproduction factor (RF) compared to nematode only treatment.

Key words: Ground, powders, *Myristica fragrans*, nematicidal activity, *Meloidogyne incognita*, sunflower.

INTRODUCTION

The Sunflower family (Compositae and also called Asteraceae) is one of the largest families in the plant kingdom. Plants of this family are found throughout the world, growing in many different environments and climates. The sunflower, *Helianthus annuus* L. is considered one of the most important oil crops, in Egypt, providing 90% for several reasons that is easily grown in most of the Egyptian land, planted in more than one agricultural cycle including alongside other Summer crops Many nematode species are found in association with Asteraceae roots. The root-gall nematode, *Meloidogyne* species can infect more than 2000 species of plants. Root-knot nematodes are most abundant and cause greater yield loss in well-drained sandy soils. These nematodes are seldom found in soils with more than 40% clay or silt. Infective larvae are most active at soil moisture levels of 40 to 60% of field capacity. Eggs may be killed in saturated soils with anaerobic conditions

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(Schwartz, 2007). Nematode infection affect crop production and quantity and decrease nutrients plant absorption by plants causing shortage of fertilizers available amount. The environmentally friendly alternatives control methods are required for nematode management. Biological control is one possible safe alternative to nematicides for disease management, and is likely to be free from toxic residual effects. The approach of combining biological control agents to manage various soil borne pathogens including plant parasitic nematodes has been investigated extensively (Al-Ghanam, 2011). Less attention has been devoted to methods which improve plant health for the purpose of increasing tolerance to existing nematode populations. Application of organic soil amendments is a traditional control method for plant-parasitic nematodes and it is considered a part of nematode-management programs (Oka, 2010). A variety of organic amendments, such as animal and green manures, nematicidal plants and proteinous wastes, are used for this purpose, but nematode control efficacy is not always satisfactory (Trivedi and Barker, 1986). The advantages of organic amendments in improving crop performance are well known (Gallaher and McSorley, 1995). *Myristica fragrans* (nutmeg) is an aromatic evergreen tree that belongs to the plant family Myristicaceae. Nutmeg is known to have an important role in plant defense, protecting against many infections, infestations, and diseases. Its uses in traditional medicine have been reported (Latha et al., 2005). Essential oils from the nutmeg seed have applications in controlling harmful organisms, and they have been shown to be toxic to insects such as cockroaches (Krishnamoorthy et al., 2001). Nutmeg essential oil showed nematicidal activity against the southern root-knot nematode *M. incognita* (Tylenchida: Heteroderidae) (Gotke and Maheswari, 1990). However, nematicidal effects of dried leave powders of *M. fragrans* against *M. incognita* have not been reported. In this study, three rates of ground leaves and fruits powders of *M. fragrans* was evaluated for their nematicidal activity against *M. incognita* infecting sun flower plants under greenhouse conditions.

MATERIALS AND METHODS

A greenhouse experiment was conducted to study the impact of three rates of *M. fragrans* leaves and fruits ground into powders in comparison with oxamyl (Vydate 24% E.C, Methyl-N'N'- dimethyl-N [(methyl) carbamyloxy]-1- thioxamidate at 0.3 ml/plant) against *M. incognita* infecting sunflower plant cv. Giza 1 as a susceptible host at 28± 3ºC. Three seeds of sunflower were separately sown in each plastic pot (15 cm), filled with 1 kg steam-sterilized sandy soil. Two weeks later after seeds had germinated, seedlings were thinned into one seedling / pot. At this time, 52 seedlings were separately inoculated with 1000 eggs of *M. incognita* collected from infected roots of coleus (*Coleus blumei)* that were extracted from infected roots by sodium hypochlorite (NaOCl) solution (Hussey and Barker, 1973). Four sunflower seedlings were left without nematode and any treatment to serve as a control. Three rates of *M. fragrans* powders (5, 10 and 20 g / pot) were separately introduced and mixed with the soil surface of each treated pot. At the same time, four sunflower seedlings with nematode received oxamyl at the recommended dose (0.3 ml/ seedling) only and another four seedlings had nematode only, while four pots without nematode and any treatment served as control. Plastic pots were arranged in a completely randomized design. Pots were watered with tap water as needed. Plants were harvested 45 days after nematode inoculation. Data dealing with plant length, fresh root and shoot weight were determined and recorded. Dry shoot weight was also estimated and recorded. Nematodes were extracted from 100 g soil using sieving and modified Baermann-pan technique (Goodey, 1957). The nematode suspension were examined using a Hawksely counting slide with an anatomy microscope to quantify the juveniles number, then the juveniles number per pot was calculated and recorded. Number of galls, eggmasses, females, and endo-parasitic forms (development stages) in roots were counted and recorded (Bybd et al., 1983). Data were subjected to analysis of variance (ANOVA) (Gomez and Gomez, 1984) followed by Duncan multiple range tests (DMRT) to compare means (Duncan, 1955).

RESULTS AND DISCUSSION

Table 1 summarizes the influence of three rates (5, 10 and 20) of *M. fragrans* powders in comparison with oxamyl against *M. incognita* infecting sunflower plant cv. Giza 1 at 28± 3ºC. Results indicate that all tested applications significantly improved sunflower plant growth characters. Moreover, all tested treatments significantly gave better results with a significant correlation between the increase in the added dose and the improvement rate in the tested plant criteria. The lowest leaves and fruits doses (5 g /pot) recorded the lowest rates of improvement in the plant length (40.4 and 51.9%), the total plant wet weight (15.0 and 52.9%) and shoot dry weight (16.7 and 125%) respectively for leaves and fruits. Meanwhile, the modest dose of leaves and fruits (10 g /pot) recorded the highest rates of improvement with values of 88.5 and 63.5; 88.9 and 75.0; 141 and 133.3% respectively for plant length, total plant wet weight and shoot dry weight. On the other hand, the highest dose of groundleaves and fruits powders of *M. fragrans* recorded intermediate results for the same tested plant measurements compared to nematode alone.

Table 2 represent the influence of three rates (5, 10 and 20) of ground leaves and fruits powders of *M. fragrans* in comparison with oxamyl on *M. incognita* reproduction criteria, juveniles in soil as wells as galls, eggmasses, females and development stages numbers on sunflower plant roots *in vivo* at 28± 3ºC. The results showed a positive correlation between increased tested dose and reduced nematode reproduction rate. The highest rate of ground leaves and fruits powders of *M. fragrans* (20 g /pot) recorded the highest reduction values in tested nematode criteria with values of 80.0 and 75.9% for final nematode reproduction and stated the lowest nematode reproduction factor (RF) compared to only nematode treatment. Moreover, the lowest rate of ground leaves and fruits powders of *M. fragrans* (5 g /pot) recorded the lowest reduction values in the tested nematode criteria

Table 1. Plant growth response of three rates of grounded leaves and fruits powders of *Myristica fragrans* in comparison with oxamyl against M. incognita infecting sunflower plant cv. Giza 1 at 28±3°C.

Treatment	Dose	*Plant growth response									
		Length of shoot (cm)	Length of root (cm)	Total plant length (cm)	Inc.%	Fresh weight (g)		Total plant F. wt (g)	Inc.%	Shoot dry weight (g)	Inc.%
						Shoot	Root				
Myristica fragrans leaves	5	50.0^{b}	23.0^{b}	73.0^{b}	40.4	14.8^{c}	2.8^{d}	17.6^{c}	15.0	1.4^{b}	16.7
	10	68.0^{a}	30.0^{a}	98.0^{a}	88.5	23.5^{a}	5.4^{c}	28.9^{a}	88.9	2.9^{a}	141.6
	20	55.0^{b}	25.0^{b}	80.0^{a}	53.8	20.5^{b}	5.0^{c}	25.5^{a}	66.7	2.8^{a}	133.3
Myristica fragrans seeds	5	54.0^{b}	25.0^{b}	79.0^{b}	51.9	19.2^{b}	4.2^{c}	23.4^{a}	52.9	2.7^{a}	125.0
	10	55.0^{b}	30.0^{a}	85.0^{a}	63.5	20.6^{b}	6.2^{b}	26.8^{b}	75.0	2.8^{a}	133.3
	20	52.0^{c}	30.0^{a}	82.0^{a}	57.7	21.4^{b}	5.2^{c}	26.6^{b}	73.9	2.8^{a}	133.3
Oxamyl +N		53.9^{c}	30.1^{a}	84.0^{a}	61.5	19.1^{b}	7.5^{a}	26.6^{b}	73.9	2.8^{a}	133.3
N alone		34.0^{d}	18.0^{c}	52.0^{c}	-	13.5^{c}	2.8^{d}	15.3^{b}	-	1.2^{b}	-
Plant free of any treatment and N		50.0^{b}	20.0^{c}	70.0^{b}	34.6	14.5^{c}	2.0^{d}	16.5^{b}	20.9	1.3^{b}	8.3

N = eggs of M. incognita. *Each value is a mean of four replicates. Mean values in each column followed by the same letter(s) did not differ at P< 0.05 according to Duncan's multiple- range test.

Table 2. Efficacy of three rates of grounded leaves and fruits powders of *Myristica fragrans* in comparison with oxamyl on development and reproduction of *M. incognita* infecting sunflower plant cv. Giza 1 at 28± 3ºC.

Treatment	Dose	Nematode population in									
		Soil (J2	Root / Plant		Final population	RF Pf/Pi	Red. %	No. of galls	*RGI	No. of Eggmasses	*EI
			Female	D.V. stage							
Myristica fragrans leaves	5	900.0^{b}	22.0^{b}	8.0^{b}	930.0^{b}	0.93	44.4	19.0^{b}	3.0	15.0^{b}	3.0
	10	406.0^{c}	12.0^{b}	5.0^{b}	423.0^{b}	0.42	74.7	12.0^{b}	3.0	2.0^{b}	1.0
	20	327.0^{c}	5.0^{b}	2.0^{b}	334.0^{b}	0.33	80.0	8.0^{b}	2.0	0.0^{b}	0.0
Myristica fragrans seeds	5	600.0^{c}	17.0^{b}	3.0^{b}	620.0^{b}	0.62	63.1	10.0^{b}	3.0	1.0^{b}	1.0
	10	420.0^{c}	15.0^{b}	3.0^{b}	438.0^{b}	0.44	73.8	11.0^{b}	3.0	1.0^{b}	1.0
	20	390.0^{c}	12.0^{b}	2.0^{b}	404.0^{b}	0.40	75.9	6.0^{b}	2.0	1.0^{b}	1.0
Oxamyl +N		300.0^{c}	5.0^{b}	2.0^{b}	307.0^{b}	0.31	81.7	4.0^{b}	1.0	0.0^{b}	0.0
N alone		2500.0^{a}	108.0^{a}	66.0^{a}	2674.0^{a}	2.67	---	110.0^{a}	5.0	100.0 ^{a}	5.0

*N = eggs of *M. incognita*. **Each value is a mean of four replicates. Mean values in each column followed by the same letter(s) did not differ at P< 0.05 according to Duncan's multiple-range test. *Root gall index (RGI) or eggmasses index (EI): O = No galls or eggmasses; 1= 1-2 galls or eggmasses; 2= 3-10 galls or eggmasses ; 3=11-30 galls or eggmasses; 4= 31-100 galls or eggmasses; 5 = More than 100 galls or eggmasses (Taylor and Sasser, 1978).

with values of 44.4 and 73.8% for final nematode reproduction and stated the highest nematode reproduction factor (0.93 and 0.4) compared to only nematode treatment (2.67). On the other hand, there was a significant difference in the number of galls and egg masses compared to nematode treatments.

Due to the importance of the root-knot nematode *Meloidogyne* spp. which causes an estimated annual crop loss of more than 5% worldwide (Sasser and Carter, 1985); including sunflower crop which contains high oil and protein for human use, the control measures to be applied all over the world is becoming a great goal. However, results of the present study initiate the promising phenomenon in suppressing plant parasitic nematodes such as the root-knot nematode *M. incognita* (the target of this work) and ameliorating plant growth parameters of sunflower with three rates (5, 10 and 20) of ground leaves and fruits powders of *M. fragrans* as abiotic factor compared to the optimum dose of oxamyl used as synthetic nematicide. The highest rate of ground leaves and fruits powders of *M. fragrans* (20 g /pot) recorded the highest reduction values in tested nematode criteria, while the lowest rate stated the lowest reduction values in tested nematode criteria. *M. fragrans* seed GC/MS, contained alpha-pinene and terpine 4-ol (4.4%) that inhibits the formation of mycotoxin like aflatoxin by *Aspergillus parasiticus* (Lawson, 1996). Our results are in accordance with those of Abdel-Rahman et al. (2013) who suggested that monoterpenoids and essential oils with a high concentration may provide potential natural nematicides and merit as botanical nematicides for the control of plant parasitic nematodes. The same author stated that oxygenated terpenoids and phenolic terpenoids exhibited higher nematicidal activity than hydrocarbons terpenoids.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Characterization of the Soil Nematode Fauna of Makerere Hill, Kampala, Uganda

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Soil nematode faunal analysis is necessary to ascertain the health status of the soil ecosystem. Composite soil samples were taken at designated sites; A, B, C and D from the Makerere Hill area, Kampala and analyzed to characterize the nematode fauna status. Soil samples were collected vertically at 0-5 cm, 5-10 cm and 10-15 cm core depths with a 5 cm wide soil auger. A total of 7,900 nematodes were collected from the study out of which 1,720 (21.8%) nematodes came from 0-5 cm core depth, 5,270 (66.7) from 5-10 cm core depth and 910 (11.52) from the 10-15 cm core depth. Species diversity showed nine orders of nematodes comprising twenty four families and forty nine species. The Order; Tylenchida had eight families and twenty five species. The Dorylaimida had six families and eleven species, The Rhabditida had families and seven species. The orders; Enoplida, Desmoscolida, Monhysteriida, Chromadorida, Araeolaimida and Tetracephalida had only one family and species each. Nematode species richness and abundance were more in the sites located at the lower fringes of the hill, induced by inherent environmental characteristics that promoted organic enrichment of the soil. The top soil (0-5 cm core depth) comprised the bacterivores c-p 1 (*Rhabditis* spp.) and c-p 2 nematodes (*Desmoscolecidae* Spp.), the 5-10 cm core depth had a composite population of all the trophic guilds but dominated by specialist obligates (plant parasitic) while the wide host range obligates (*Meloidogyne* spp., *Pratylenchus* spp. and *Tylenchus* spp.) occurred at 10-15 cm core depth. There was a large assortment of specialist parasites; *Aphelenchus* spp., *Aphelenchoides* spp., *Aphastimatylenchus nigeriennsis* and *Trichodorus* spp., occasioned by vegetation characteristics of the study area. The study area is a compendium of divergent habitats with peculiar ecomorphological characteristics that can serve as a reference in future environmental impact evaluation studies in relation to soil nematode faunal integrity in Uganda.

Key words: Soil nematodes, species diversity, abundance, bacteriovores, specialist obligates, ecomorpological characteristics.

INTRODUCTION

The nematodes are ubiquitous in both aquatic and terrestrial environments; a characteristic that makes them very significant biological agents in the assessment and evaluation of the environment (Heip et al., 1985; Traunspurger, 2002; Manzanilla and Hunt 2004; Traunspunger, 2002; Nzeako et al., 2014; Hagerbaumer, et al., 2015 and Nzeako et al., 2016). In the terrestrial environment soil nematodes are great bioindicators of

soil environmental changes, due to their responses to slight alterations to the soil physicochemical dynamics (Xiaoming et al., 2013, Cesarz et al., 2015). The assemblage and community structural dynamics of the nematode meiofauna are great tools for the evaluation of soil processes and plant conditions in terrestrial ecosystems (Wang et al., 2009; Pen Mouratou et al., 2010; Traunspurger et al., 2006; Zhang et al., 2012). The abundance or scarcity of nematodes in any natural aquatic or terrestrial environment is an index of the health status of such environment (Heip et al., 2000; Ferris and Benelman, 2003; Cesarz et al., 2015). As a significant component of the environmental indicator system, the nematode meiofauna are of great use in identifying habitats with poor ecological status and relate them to chemical pollutants or other types of stressors in the environment, including; hydro-morphological modifications and climate change (Von der Ohe et al., 2007; Von der Ohe and Goedkoop, 2013; Cesarz et al., 2015). However, the close relationship between soil characteristics and nematode abundance in various functional guilds could be exploited in developing a universal standard for evaluating the faunal integrity of an ecosystem (Fiscus and Neher, 2002; Nzeako et al., 2014; Angaye et al., 2015a).

Relevance of the nematode fauna in environmental impact assessment

It is a fact that the geographical characteristics of an area contributes to its biodiversity integrity (Seiyaboh et al., 2010; Angaye et al., 2015b). Zhang et al. (2012) recognized that forest types and elevations as crucial factors in the distribution of soil nematode communities. The influence of elevation gradient as a natural force that determines ecological and evolutionary responses of biota to environmental changes cannot be over emphasized (Korner, 2007; Zhu et al., 2010). To this end; Yeates (2007) opined that higher biodiversity and species richness in forest soils at lower elevations are associated with more suitable and resilient ecosystems. However, in most prevalent ecological settings; nematode richness is not entirely influenced by elevation (Zhang et al., 2012). Although, it has a significant influence in the assortment and variations in soil nematode community composition it is not the only limiting factor to nematode biodiversity (Popovici and Ciobanu, 2000).

It is expected that nematode community characteristics should be included in any standard environmental assessment and monitoring study. Sadly, this envisaged inclusion of nematodes in current numerous environmental studies is yet to be actualized, especially in sub Saharan Africa. The non-inclusion of the nematode meiofauna in environmental impact assessments in Sub Saharan Africa may be due to myriads of reasons, including; 1) the idiosyncrasies of environmental investigators saddled with environmental assessment studies, which may hamper objectivity and inclusiveness; 2) the flux in the taxonomy of soil nematodes; 3) the in-extensiveness of the existing taxonomy to non-parasitic species; 4) the microscopic nature of most free living nematode species that undermines sampling, collection and assortment of reasonable quantities of specific nematodes for inclusive soil analysis; and 5) the scarcity of qualified nematologists. Currently, in sub-Saharan Africa, soil nematodes are not readily considered as parasites and pests of great economic significance, due to their sublime pattern of pathogenicity (Nzeako et al., 2011). This scenery dovetails into environmental impact assessments studies conducted in Africa, where numerous environmental impact evaluation reports have been accepted without the critical nematode meiofauna component.

It is pertinent for any standard environmental study to include the nematode meiofauna because of their important roles in the food web and mineral cycle of the biota. According to Ferris et al. (2001); nematode faunal analysis based on the relative weighted abundance of c-*p* classes; maturity index provides a quantitative measure of the nematode community structure and the probable condition of the soil food web. Colonizer-Persister (*c-p*) values of nematode taxa ordinated on a 1-5 scale based on *r-k* life-history characteristics are useful in interpreting the trophic status of the soil food web in different habitats (Bongers et al., 1990, 1997; Ferris and Bongers, 2012). Maturity index of soil nematodes illustrates the sensitivities of soil nematode fauna to ambient ecological disturbances. It is an ecological measure for the state of colonization and succession based on the composition of the nematode fauna after interferences, including; the monitoring of xenobiotic induced stresses in the soil (Bongers et al., 1997). Maturity index analysis also comprises calculation of indices of food web enrichment (EI), structure index (SI) and channel index (CI) evaluations that provide information about below ground ecological processes. EI indicates the responses of primary decomposers (bacteria and fungi) to available resources, SI indicates the prevalence of trophic linkages in the soil food web, and CI provides information on the prevalent decomposition channels in the soil food web (Briar et al., 2012). However, Bongers et al. (1999) expressed some reservations about the adoption of nematode maturity index-values as the absolute environmental status indicator, because; it only gives a rough indication of the extent of disturbance, and unable

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to identify the inherent dominant stress factors. It is clear that soil nematodes are sensitive to a wide range of environmental parameters which should unequivocally consolidate their position as a bio-indicators (Urkmez et al., 2014). For instance, it has been observed that the *Rhabditis* species are indicators of organic enrichment in the terrestrial environment and could play a great role in the mineralisation process as well as in the distribution of certain micro-organisms in the environment.

The Eastern region of sub Saharan African is a strong agrarian region and witnesses a lot of upsurge of arthropod pest evasions. However, the region's environment is also invaded by soil nematodes of various species, which are grossly under-reported due to the reasons earlier stated (Talwana et al., 2015). This study is aimed at characterising the soil nematode of the Makerere hill area in Kampala, where the Makerere University is situated in Uganda. This has become necessary since there is dearth of literature on this subject in relation to the study area.

MATERIALS AND METHODS

Study area

Makerere lies at exactly 2.5 km by road north of Kampala central business district which is part of the Kewempe Division. Makerere is located within coordinates 0° 20' 6.00"N, 32° 34' 12.00"E (Latitude: 0.3350; Longitude: 32.5700). It is bordered by Bwaise to the north, Mulago to the east, Wandegeya and Nakasero to the southeast, Old Kampala is also located to the south, Naakulabye to the southwest. Kasubi and Kawaala lie to the west of Makerere (Aakansha, 2014).

Description of the study area (Makerere University)

The study was conducted in Makerere area, located about 5 km to the North of Kampala city, the capital of Uganda. Makerere hill is one of the several hills that make up Kampala district other hills neighboring Makerere include; Kasubi hill to the West, Nakasero hill to the East, old Kampala hill to the South, Mulago hill to the North East and Kawempe to the North. Makerere hill is the home of Makerere University main campus covering 300 acres of land area. Makerere university is the oldest and biggest University in Uganda established as early as 1922 as a technical school. Today, the University has up to 9 colleges and one school with an average number of 40,000 undergraduate students and 3,000 graduate students.

Makerere Hill is located $00°21^{1}00^{1}$N $32°34^{1}03^{1}$E covering a total land area of 300 acres. Like the rest of Kampala district, Makerere Hill has a tropical rain forest climate according to the Koppen-Geiger climate classification system. The area receives a bimodal kind of rainfall with two wet seasons; the shorter rain season that is, between February and June receives substantially heavier rainfall per month with the month of April leading with an average precipitation of 169 mm. The average annual temperature is 21.3°C and about 1293 mm of precipitation falls annually.

Collection of samples

Four sampling stations designated; A, B, C, and D with multiple sites were selected within the University campus, Station A: The University Hall- Eastern Kampala Hill (Long: N00°20'079"-00°19'930"; Lat: E 032°34'317" - E032°34'339"; Elevation: 1638±434 m; Total Ascent: 4168±11 m) in eastern part of the campus. Station B; Makerere Garage 2-Western Kampala Hill (Long: N00°19'865"- 00°20'118"; Lat: E 032°33'984" - E032°33'887"; Elevation: 1237±401 m; Total Ascent: 4168±07 m) in the western part of the campus. Station C-Faculty of Food Science Area-Northern Kampala Hill (Long: N00°20'274"-00°20'309"; Lat: E 032°33'961"-E032°33'917"; Elevation: 1251±27 m; Total Ascent: 4175±03 m) in the northern part of the campus, and Sample Station D-Social Sciences Area (Long: N00°19'716"- 00°19'948"; Lat: E032°19'948"- E032°34'110"; Elevation: 1636±02 m; Total Ascent: 4134±19) in the southern part of the university.

Composite soil samples were collected randomly with the aid of a soil auger. Samples were collected from designated sites at depths of 0-5 cm, 5-10 cm and 10-15 cm respectively. These were put into properly labelled polythene bags to prevent dehydration. A total of 600 samples were collected, 60 from each location, these were taken to the laboratory for extraction of nematodes. The samples from each collection site were composited and subdivided in five sets. Nematodes in the subsets were extracted using the modified Bearmann's extraction (Barker et al., 1969; Nzeako et al., 2014) and the sieving methods (Thorne, 1961; Barker et al., 1985; Kimenju et al., 2007) while identification was according to Goodey and Goodey (1963) using the compound and stereoscopic microscopes.

About 100 g of the composite soil sample from the designated sites were proceeded at soil laboratory at the college of agricultural and environmental sciences of Makerere, University for physical and chemical properties assessment. About 200 g of each composite soil sample was used for nematode extraction. Nematodes were extracted from each sample using the active method of nematode extraction as described by Coyne et al. (2007). After extraction, the nematode aliquots from each composite sample was kept in a well labeled universal sample bottle and kept in the refrigerators maintained at 4°C until further analysis. Later, the nematode extracts were fixed in 5% formaldehyde, labelled and stored in universal sample bottles for further examination.

Group c-p1 has generation times of only some days, high colonization ability, and tolerance to environmental stress. They have a high metabolic activity. Their population growth under conditions with rich food is explosive. Nematodes assigned to c-p 2 have a short generation time, they respond more slowly to environmental enrichment than c-p1 nematodes but increase in abundance under stressed conditions. They occur in all environments, and very tolerant of pollutants and other disturbances (Herris and Bongers, 2009). Group c-p3 is an intermediate class, has longer generation time than the previous class and includes some Chromadoridae (recalibration made at genus level) and relatively sensitive to disturbances. Nematodes assigned to the group c–p4 are characterized by a long generation time, permeable cuticle and recognized as highly sensitive to stress and pollutants. Extreme persisters are composed of larger omnivores and predators as Enoplidae and Leptosomatidae (c-p 5). They present with a generation time of one year, low colonization ability, low reproduction rates, have a permeable cuticle, are very sensitive to pollutants and other disturbances in the marine meiobenthos e.g. the *r*-strategists (Warwick, 1986).

Laboratory analysis

The composite soil samples were air-dried, sieved (2 mm) and subjected to physichochemical analysis following standard methods described by Okalebo et al. (2002). Soil pH was measured in a soil water solution ratio of 1:2.5; organic matter by potassium dichromate

Table 1. The physicochemical characteristics of the sampling stations.

Study area	Sample station	pH	OM (%)	Sand	Clay	Silt
University Hall Site1	A	5.9	4.35	64.0	26.0	10.0
Makerere Garage Site 2	B	5.7	3.06	46.0	44.0	10.0
FST Area site 3	C	6.1	3.38	48.0	44.0	8.0
Social Sciences site 4	D	6.0	3.55	48.0	44.0	8.0

*Global standard: pH range- (forest soil 3-5; Humid Climate soil arable soil 5-7) by McCauley et al. (2017); % Organic Matter (OM) variable, A-Elevation: 1638±434 m; Total Ascent: 4168±11 m); B-Elevation: 1237±401 m; Total Ascent: 4168±07 m); C-Elevation: 1251±27 m; Total Ascent: 4175±03 m; D- Elevation: 1636±02 m; Total Ascent: 4134±19).

wet acid oxidation method; and particle size distribution (texture) using the Bouyoucos (Hydrometer) method.

Data analysis

Data was analyzed using (ANOVA) while the Shannon Wiener Diversity Index was used to analyzed nematodes community dynamics.

RESULTS

Physicochemical characteristics of sampling stations

Assessments of the physicochemical parameters in the study were restricted to the pH, % organic matter (OM) and soil aggregates (soil grain composition) of the sampling stations. There was inconsistency in acidity (Table 1). The mean pH values oscillated between recorded values for forest soil and humid arable soil types based on the reports of McCauley et al. (2017). The organic matter (OM) composition of all the sampling stations indicated high humus contents with slight variability across the stations; however, the highest (OM) values were recorded in station A. The soil aggregate composition of the sampling stations or collection points showed bulky constitution with relatively high ratios of clay and silt to sand in all stations except in sampling station A. The derived soil aggregate ratio in the study deviates from the proportionately high ratio of sand to clay and silt characteristic of normal forest soil (Table 1).

Composition of soil nematode fauna in Makerere Hill Uganda

About nine orders of soil nematodes were recovered from the sampling stations comprising twenty four families and forty nine species. The order; Tylenchida had eight families and twenty five species. The Dorylaimida had six families and eleven species, The Rhabditida had four families and seven species. The orders; Enoplida, Desmoscolida, Monhysteriida, Chromadorida, Araeolaimida and Tetracephalida had only one family and one species each. Out of the twenty five species in the order Tylenchida; five genera; *Aphenlenchoides* spp., *Aphenlenchus* spp., *Liaphelenchoides* Spp., *Metaphelenchoides* Spp. and *Seniura* Spp., were free living with variable trophic affiliations while the remaining were obligate herbivores (plant parasitic). Aside, *Trichodorus* spp., and *Xiphenema* spp., all the members of the orders; Dorylaimida (*Cobbonchus* spp., *Caloosia* spp., *Dorylaimus* spp., *Trachypleurosum* spp., *Trichorus* spp., *Longidorus* spp., *Sectinema* spp., *Paralongidorus* spp., and *Xiphenema* spp.) and Rhabditida, in the study were free living with different trophic affiliations ranging from bacteriovore to fungivore or predatory. This situation was also encountered in the order; Desmoscolida, Chromadorida, Araeolaimida, and Tetraocephalida. There was no significant difference (P>0.05) in nematode occurrence within different sampling stations and sites in the study.

There was great variability in population of nematodes recovered from the various sampling sites, which was greatly associated with the plant cover type (vegetation) of the ecosystem. A total of 990 nematodes (12.64%) was recovered from sampling station/site A; comprising 5 orders. Station A was made up of relatively undisturbed vegetation with canopy trees between 20-30 m high and undergrowth of compact grass except for the mono cropping of Musa species of plants in the area. The soil was bulky due to high retention of water and poor light penetration. Sampling station/ site B had a total of 600 (7.66%) nematodes comprising 5 orders and 23 species. The area possessed similar characteristics with site A except that is it is located at a relatively high altitude. Sampling station/ site C comprised mainly of grasses that are frequently disturbed antropologically. Here, 5080 (65.25%) nematodes were recovered, comprising 4 orders and 15 species. The nematode fauna domiciled in site C were mainly plant obligates. Site D, characterized by open grass planes with isolated clusters of undisturbed deciduous trees (between 20-30 m) had a total of 1130 (14.43%) nematodes; comprising 6 orders and 23 species (Tables 4 to 8).

Vertical variation in the nematodes distribution and concentration showed that 21.77% of the total population of nematodes occurred at the top soil comprising mainly the bacterivore c-p 1 (*Rhabditis* spp.) and c-p 2 nematodes. The 5-10 cm core depth harbored 66.71% of

the total population comprising nematodes of all guilds especially the specialist obligates (plant parasitic), while the 10-15 cm core depth had 11.52% comprising mainly the w ide host range obligates that parasitize tap root systems (*Meloidogyne* spp., *Pratylenchus* spp. and *Tylenchus* spp.). The 0-5 cm core depth recorded the highest abundance of nematodes in the sampling stations except in sampling station C. Nematode species diversity in the different sampling stations was highest in 0-5 cm core depth (Table 2). Cumulatively, thirty nine genera and species of nematode were recovered from the 0-5 cm core depth, 22 from the 5-10 cm core depth and 15 from the 10-15 cm core depth from the entire study (Table 2). The species diversity and richness of nematode meiofauna in Makerere Hill, Kampala was high (Table 4a and b).

Functional role of nematodes in the study

There was great variability in the functional roles of soil nematodes encountered in the study. Nematode occurrence and abundance was both site and depth related. The top soil showed relatively more nematode diversity and species richness, with little abundance. The 5-10 cm core depth recorded the highest population of nematodes in the study with *Rhabditis terresteris* having the greatest occurrence. Nine genera and species of soil nematodes occurred in the three core depths considered in this study; nineteen in two depth categories and twenty nine in only one depth category in no particular order (Tables 2 and 3). However, the obligate herbivores occurred more below the 10-15 cm depth while the free living species were common at the top soil (0-10 cm). The maturity index evaluation nematodes of the Makerere Hills showed variability in the sampling areas. The four sampling stations designated; Station A had MI value of 2.1 and PPI of 3; Station B; Makerere Garage 2.4 had MI of 2.4 and PPI of 5.85, Station C-Faculty of Food Science Area-Northern Kampala Hill had MI of 0.75 and PPI of 5.25, and Sampling Station D- Social Sciences Area had MI value of 0.26 and PPI value of 0.21. Nematode diversity and species richness were high as indicated in Tables 2 to 4 in the study.

DISCUSSION

Physicochemical characteristics of the sampling stations

The study areas and sampling sites in the Makerere hill ecosystem showed great variability in physichochemical properties consequently, influencing the general distribution and vertical population dynamics of the nematode fauna in the respective sampling stations. The ambient pH values of the various sampling stations exhibited slight discrepancies, which concurred with result from a study in forested soil by Mulder et al. (2005) who stated very minute alterations in the ambient physicochemical characteristics of a habitat usually lead to great disparities in the endemic meiofaunal population dynamics in ecological settings. The pH values obtained from the various sampling sites influenced nematode community composition (Tables 1 to 8).

The association between organic content of the soil and nematodes assemblage was clear in the study as nematode specificity was disproportionately monospecific in sites that were frequently naturally enriched (e.g. bird droppings etc). However, none-anthropologic enrichment processes were observed in study stations; 1-4, which influenced the vertical nematode faunal distribution pattern; a similar trend to the observation of Nzeako et al. (2015) in turf grass fields in Port Harcourt. It was observed that *Rhaditis* species exhibited relatively high abundance due to the continuous none-anthropologic enrichment of the environment (leaf litter and excreta of birds). This occurrence confirmed reports by Ferris and Bongers (2006) that nematodes are clear indicators of organic enrichment thereby are reliable bioindicators of organic influx in both the aquatic and terrestrial environments. The study opines that *Rhaditis terrestrix;* a bacteriovore in c-p 1 with short generation life span indicated continuous enrichment of the sampling sites. The observed variability in organic matter augmentation due to natural processes in this study was directly associated with vegetation type which comprised mainly top storey ornamental plants that housed many domestic and exotic avian species (Zhang et al., 2012). It was observed that the rich array of canopy trees, averaging 20-25 m in height had great ornithological significance as they harboured great diversity of domestic and exotic birds. Organic content had the greatest influence on the top-down control of microbes by soil nematode and the vertical distribution of the nematode fauna (Figures 3 to 6) in the study (Yeates, 2007) as evidenced by the abundance of bacterivores on the top segment of the soil. The topography of the study area and sampling stations also influenced the distribution and diversity of soil nematodes fauna. Zhang et al. (2012), stated that forest types and elevations greatly influence the distribution of soil nematodes communities. Although, Popvici and Ciobanu (2000) asserted that nematode species richness is not entirely dependent on elevation; a point this study up-holds because, the variability in population dynamics of the nematode meiofuana was greatly patterned by site specific characteristics such as vegetation, moisture content, pH, temperature, and organic content, that were not strictly dependent on elevation. In this survey, soil grain composition and elevation were considered as contributory factors to nematodes population dynamics (Figure 6). Nematode species richness (Tables 6 to 8) and abundance (Figure 1) were more in the sites located within the lower fringes of the hill (Korner, 2007; Zhu et

Table 2. Composition of soil nematodes recovered from different sampling stations.

Nematode species	Site 1	Site 2	Site 3	Site 4	Overall total (%)
Acontylus vipriensis	**0**	**0**	**0**	60	60 (0.76)
Anomyctus xenarus	0	20	0	20	40 (0.51)
Aphasmatylenchus Spp.,	20	10	0	60	90 (1.14)
Aphelenchoides averiae	0	30	0	10	40(0.51)
Aphelenchus Spp.,	0	0	0	130	130(1.65)
Aorolaimus helices	0	0	10	0	10(0.13)
Aphenlenchoides sacchicti	0	10	0	0	10(0.13)
Berkernema auernei	0	20	0	0	20(0.25)
Caloosia Spp.,	10	0	0	0	10(0.13)
Cephalobus Spp.,	0	0	0	10	10(0.13)
Chrptonchus Spp.,	10	0	0	20	30(0.38)
Criconema Spp.,	30	0	20	10	60 (0.76)
Cobbonchus Spp.,	0	10	0	0	10(0.13)
Desmoscolecidae Spp.,	80	0	0	0	80(1.01)
Diplogaster spp.,	0	10	0	0	10(0.13)
Ditylenchus Spp.,	0	10	0	0	10(0.13)
Dorylaimide Spp.,	0	0	0	20	20(0.25)
Gracilercus audriellus	0	30	0	0	30(0.38)
Helicotylenchus dihystera	20	0	130	60	210(2.66)
Hemicriconemoide Spp.,	0	10	0	0	10(0.13)
Laimaphelenchus Spp.,	0	10	0	0	10(0.13)
Longidorus Spp.,	20	0	60	40	120(1.52)
Meloidogyne Spp.,	170	120	110	90	490 (6.20)
Mesorhabditis Spp.,	0	10	0	0	10(0.13)
Metaphelenchus steiner	0	10	0	0	10(0.13)
Monhystera Spp.,	0	10	0	0	10(0.13)
Paracyatholaimus intermedius	0	0	40	20	60 (0.76)
Paralongidorus Spp.,	0	10	0	0	10 (0.13)
Paraplectnema strands	0	20	0	0	20(0.25)
Paratrophus Spp.,	0	0	110	0	110(1.39)
Paratylenchus Spp.,	120	20	0	0	140(1.77)
Pratylenchus Spp.,	130	20	110	170	430(5.44)
Rhabditis Spp.,	20	70	4260	70	4420(55.94)
Rhabditiopharnes Spp.,	0	0	0	20	20(0.25)
Rotylenchus Spp.,	10	0	90	10	110(1.39)
Scutellonema Spp.,	0	0	0	30	30(0.38)
Sectonema Spp.,	0	0	10	0	10(0.13)
Seinura Spp.,	0	0	20	0	20(0.25)
Swageria Spp.,	0	0	0	80	80(1.01)
Tetracephalus Spp.,	0	0	0	30	30(0.38)
Trachypleurosum andrassey	0	10	0	0	10 (0.13)
Trophonenema arenarium	110	0	0	0	110(1.39)
Trichodorus Spp.,	0	20	0	0	20(0.26)
Tylenchus Spp.,	70	50	20	70	210(2.66
Tylodorus acuminatus	170	10	120	0	300(3.79)
Tylopharynx foetidus	0	50	0	30	80(1.01)
Turbatrix Spp.,	0	0	0	40	40(0.51)
Xiphenema radicicola	0	0	70	30	100(1.27)
Total (%)	990(12.64)	600(7.66)	5180((65.26)	1130(14.43)	7900

Table 3. Average of nematode population at different depths and sampling stations.

Core depth (cm)	Site1	Site 2	Site 3	Site 4	Overall total (%)
Core 0-5	550(31.98)	270(15.69)	370(21.51)	530(30.81)	1720(21.77)
Core 5-10	210(3.98)	220(4.17)	4600(87.29)	240(4.55)	5270(66.71)
Core 10-15	230(25.27)	110(12.09)	210(23.08)	360(3956)	910(11.52)
Overall Total (%)	990 (12.64)	600 (7.66)	5180 (65.26)	1130 (14.43)	7900

Table 4a. Ecological indices used in the study.

Order *q*:	0	1	2	3	4	∞
Generalized Mean:	harm	geom	avg	Rms	-	Inf
Hill Numbers -True Diversity ^{q}D:	15.00	10.20	8.50	7.79	7.39	5.82
Renyi Entropy ^{q}H:	2.71	2.32	2.14	2.05	2.00	1.76

Table 4b. Ecological indices used in the study.

Richness $R = {}^{0}D$:	15.00
Shannon Entropy $H' = \ln({}^{1}D)$:	2.323
Shannon's equitability H'/H_{max}	85.8%
Simpson Dominance $\lambda = 1/{}^{2}D$	11.8%
unbiased (finite samples):	11.7%
Gini-Simpson Index (1-λ)	88.2%
unbiased (finite samples):	88.3%
equitability □/(1-□$_{max}$):	94.5%
Berger-Parker Index max(p_i)=1/$^{\infty}D$	17.2%

al., 2010). The study partly agrees with Yeates (2007), that higher diversity and species richness occurred in forest soils at lower elevations occasioned by suitable and resilient ambient conditions. In the Makerere hill, nematode assemblage at the lower elevations was occasioned by the sedimentation, leaching and drainage pattern of the ecosystem that accumulate nutrients at water-hold pockets in the lower reaches of the hill. Consequently, there was an abundance of c-p1 nematodes (*Coloosia paxi*, *Cryptonchus* spp., *Desmoscolecidae* spp., *Paracyatholaimus* spp., *Swageria* spp., *Tetracephalus* spp. and *Trophinenema arenarium*) in sampling sites (A and D) located at the lower fringes of the study area (Tables 4 and 6). This scenario accentuates the claim by several researches that the c-p1 guild of nematodes are short lived, tolerant to pollutants and indicate organic matter decomposition (Ferris, 2010, Ferrris and Bongers, 2006, 2009; Ferris et al., 2004; Yeates, 2007; Popvici and Ciobanu, 2000).

Composition of soil nematode fauna in Makerere Hill Uganda

The study revealed the great biodiversity of soil nematodes in Makerere hill, Kampala, however, the variability in distribution in relation to the sampling stations indicated different ambient limiting factors on the soil nematode faunal integrity (Figures 1 and 2.). The recorded high species richness and abundance observed in all the sampling sites indicated favorable environmental conditions such as high organic content, relatively acidic pH and even composition of soil aggregate that enhanced nematode community bionomics (Xiaoming et al., 2013). The abundance of plant parasitic nematodes in all the sample sites confirmed the abundance of suitable plant hosts for the obligate nematode species. The study revealed a large assortment of specialist parasites of the foliar region of plants such as; *Aphelenchus* spp., *Aphelenchoides* spp., *Aphastimatylenchus nigeriennsis* and *Trichodorus* spp. Also, the presence of obligate herbivores like the *Meloidogyne* spp., and *Pratylenchus* spp., with wide host range showed divergent trends in the functional roles of the soil nemafauna of the rhizosphere. This scenario may have been occasioned predominantly by enhanced soil fertility and availability of variable suitable hosts (Renco and Kovack, 2012). The observed trend is in agreement with Bongers et al. (1997) who opined that high plant parasitic nematode index (PPI) and maturity index (MI) in a habitat showed divergent trends

Table 5. Composition of soil nematode fauna in sample site 1.

Nematode species	Core depth (cm)			Total (%)	Frequency	c-p value
	0-5	6-10	10-15			
Aphasmatylenchus spp.	20	0	0	20 (2.02)	2	3
Caloosia paxi	0	10	0	10 (1.01)	1*	4
Criconema spp.	30	0	0	30 (3.03)	3	3
Cryptonchus spp.	10	0	0	10 (1.01)	1*	4
Desmoscolecidae spp.	80	0	0	80(8.08)	8*	3
Helicotylenchus spp.	10	10	0	20 (2.02)	2	3
Longidorus spp.	20	0	0	20 (2.02)	2**	1
Meloidogyne spp.	70	60	40	170 (11.17)	17	3
Paratylenchus spp.	50	0	70	120(12.12)	12	2
Pratylenchus spp.	20	110	0	130 (13.13)	13	3
Rhabditis spp.	20	0	0	20 (2.02)	2**	1
Rotylenchus reniformis	0	10	0	10 (1.01)	1	3
Trophinenema arenarium	110	0	0	110(11.11)	11*	3
Tylenchus spp.	50	10	10	70(7.07)	7	2
Tylodorus acuminatus	60	00	110	170(11.17)	17	2
Total (%)	550 (55.55)	210 (21.21)	230 (23.23)	990		

F= frequency, *Nematodes within c-p value 1 and **nematodes above c-p value 1, but not obligate herbivores, Maturity Index (MI) = 2.1, Plant Parasitic Index (PPI) =3.

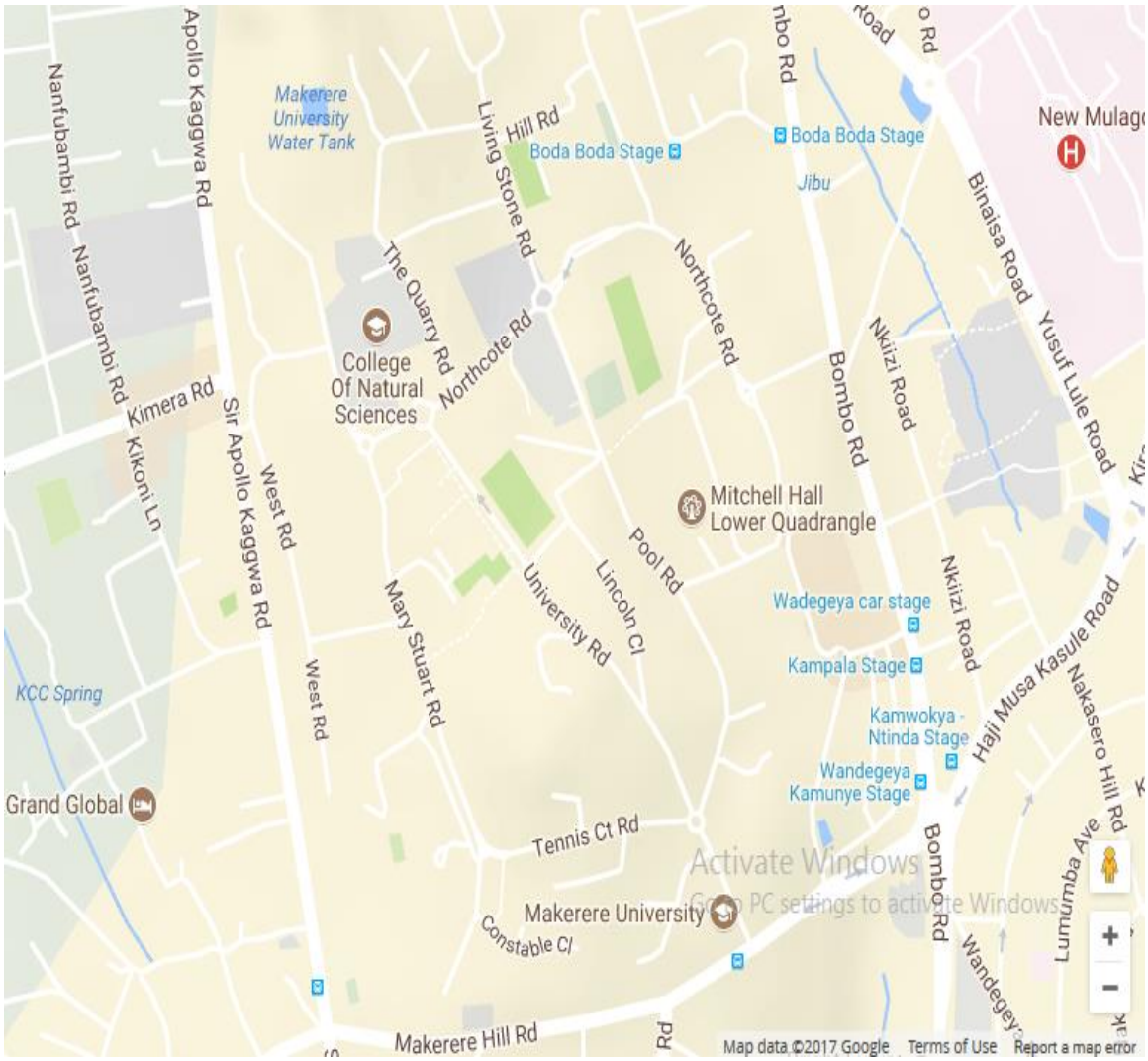

Figure 1. Map of Study Area a) Site one, b) Site two, c) Site three, d) Site four

in the functional roles of soil nemafauna community composition due to multiple sources of nourishment. The variability in vegetation pattern of the sampling stations induced by anthropologic influences are contributory to the nematode faunal distribution and this predisposed some sites to the abundance of specific nematode e.g. the Aphelenchoides and the free living species (geographical specificity).

Organic enrichment of the soil can stimulate the development of great population of micro-organisms that interact with free living stages of soil nematodes of different taxa. This interaction greatly impedes the plant parasitic nematodes infectivity and improve soil nutrient status, physical properties of soil, water retention, water infiltration, permeability, aeration and plant growth (Von der Ohe et al., 2007; Von der Ohe and Goedkoop, 2013; Urkmez et al., 2014). Many studies have focused on the different types of organic amendments as suppressants of plant parasitic nematodes, especially root-knot nematodes, because of their large host range and biological potential (Raquel, 2012; Angaye et al., 2015b; Imafidor, et al., 2016; Elele et al., 2017).

Functional role of nematodes in the study

The Makerere hill ecology depicts great environmental heterogeneity that provides species with diverse habitats and niches that host diverse species occasioned by adaptation, convergence, divergence selectivity and speciation in evolutionary processes (Manzanilla- Lopez and Hunt, 2004). The study showed the structural and functional roles of soil nematodes in the ecosystem (Ferris and Bongers, 2006; Haegeman et al., 2012; Raquel, 2012). The study is a low budget evaluation of the nematode fauna in the tropics, yet indicates; an

Table 6. Composition of soil nematode fauna in sample site 2.

Nematode species	Core depth (cm)			Total (%)	Frequency	c-p value
	0-5	6-10	10-15			
Anomyctus xenarus	0	20	0	20(3.33)	2	2
Aphasmatylenchus spp	10	0	0	10(1.67)	1	3
Aphelenchoides averiae	10	20	0	30(5.0)	3*	2
Aphenlenchoides sacchicti	0	10	0	10(1.67)	1	2
Berkernema auernei	20	0	0	20 (3.33)	2	5
Cobbonchus spp.	0	10	0	10 (1.67)	1*	4
Diplogaster spp.	0	10	0	10(1.67)	1**	1
Ditylenchus spp.	0	0	10	10(1.67)	1	2
Gracilercus audriellus	30	0	0	30 (5.0)	3	3
Hemicriconemoide spp.	0	0	10	10(1.67)	1	2
Lasmaphelenchus spp.	0	10	0	10(1.67)	1*	5
Meloidogyne spp.	60	20	40	120(20.0)	12	3
Mesorhabditis spp.	10	0	0	10(1.67)	1**	1
Metaphelenchus steiner	10	0	0	10(1.67)	1*	4
Monhystera spp.	0	0	10	10(1.67)	1**	1
Paralongidorus	10	0	0	10(1.67)	1*	5
Paraplectnema strands	10	0	10	20(3.33)	2*	5
Paratylenchus spp.	20	0	0	20(3.33)	2	2
Pratylenchus spp.	0	20	0	20(3.33)	2	3
Rhabditis spp.	20	50	0	70(11.67)	7**	1
Trachypleurosum andrassey	10	0	0	10(1.67)	1	4
Trichodorus	20	0	0	20(3.33)	2	4
Tylenchus spp.	20	10	20	50(8.33)	5	2
Tylodorus acuminatus	10	0	0	10(1.67)	1	2
Tylopharynx foetidus	0	40	10	50(3.33)	2**	1
Total (%)	270(45.0)	220(36.67)	110(18.33)	600		

F= frequency, *Nematodes within c-p value 1 and **nematodes above c-p value 1 but not obligate herbivores, Maturity Index (MI) =2.4, Plant Parasitic Index (PPI) = 5.85.

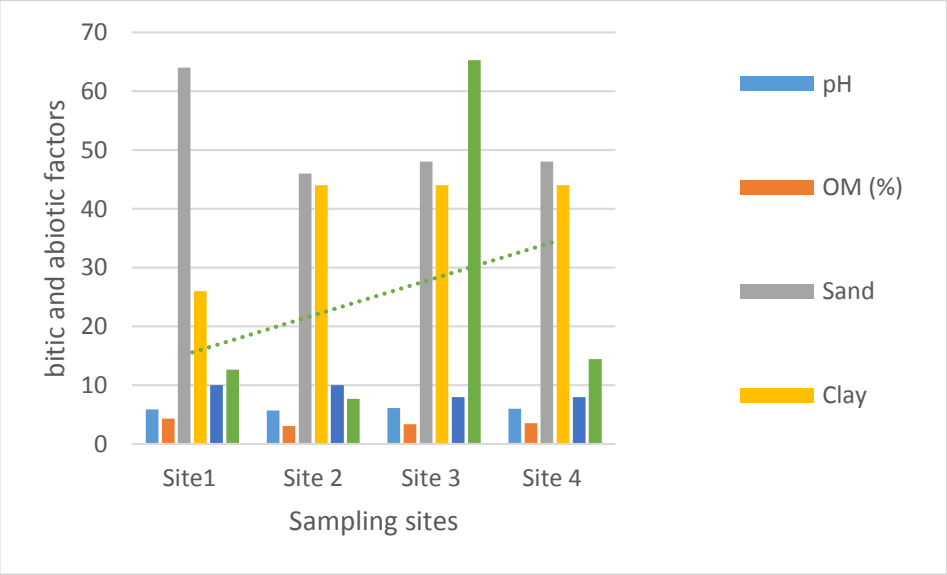

Figure 2. Relationship between ambient conditions and nematode population.

Table 7. Composition of soil nematode fauna in sample site 3.

Nematode Species	Core depth (cm)			Total (%)	Frequency	c-p value
	0-5	5-10	10-15			
Aorolaimus helices	10	0	0	10(0.19)	1	3
Criconema Spp.	10	0	10	20(0.39)	2	3
Helicotylenchus dihystera	30	50	50	130(2.56)	13	3
Longidorus Spp.	0	0	60	30(1.18)	3	1
Meloidogyne Spp.,	0	110	0	110(2.16)	11	3
Paratrophus lobotus	30	80	0	110(2.16)	11	5
Pratylenchus Spp.	20	50	40	110(2.16)	11	3
Paracyatholaimus inthermedius	30	00	10	40(0.78)	4	2
Rhabditis terrestris	50	4200	10	4260(83.85)	426**	1
Rotylenchus buxophilus	60	20	10	90(1.37)	9	3
Sectonema Spp.	10	0	0	10(0.19)	1*	2
Seinura Spp.	20	0	0	20(0.39)	2*	2
Tylenchus Spp.	0	0	20	20(0.39)	2	2
Tylodorus acuminatus	100	20	0	120(2.36)	12	2
Xiphenama Spp.	0	70	0	70 (1.37)	7	5
Total (%)	270 (5.31)	4600 (90.55)	210 (4.13)	5080		

F= frequency, *Nematodes within c-p value 1 and **nematodes above c-p value 1 but not obligate herbivores, Maturity Index (MI) = 0.75, Plant Parasitic Index (PPI) =5.25.

Table 8. Composition of soil nematode fauna in sample site 4.

Nematode species	Core depths (cm)			Total (%)	Frequency	c-p value
	0-5	5-10	10-15			
Acontylus vipriensis	50	10	0	60 (4.42)	6	3
Aphasmatylenchus spp.	0	20	40	60 (4.42)	6	3
Aphelenchoides averiae	0	10	0	10 (0.88)	1*	5
Aphelenchus spp.	110	0	20	130(11.50)	13*	2
Cephalobus spp.	10	0	0	10(0.88)	1*	2
Chryptonchus tritis	0	0	20	20(1.77)	2*	4
Criconemoides spp.	10	0	10	20(1.77)	2	3
Dorylaimide spp.	0	0	20	20(1.77)	2*	4
Helicotylenchus spp.	0	20	40	60(5.31)	6	3
Longidorus spp.	0	10	30	40(3.54)	4	1
Meloidogyne spp.	0	60	30	90(7.96)	9	3
Pratylenchus spp.	110	20	40	170(15.04)	17	3
Paracyatholaimus intermedius	0	20	0	20(1.77)	2*	2
Rhabditis spp.	40	20	10	70(6.19)	7**	1
Rhabditopharnes spp.	0	0	20	20(1.77)	2**	1
Rotylenchus spp.	10	0	0	10(0.88)	1	3
Scutellonema spp.	30	0	0	30(3.54)	3	3
Swageria spp.	0	10	70	80 (7.08)	8*	5
Tetracephalus spp.	30	0	0	30(3.54)	3*	3
Turbatrix spp.	40	0	0	40(3.54)	4**	1
Tylenchus spp.	50	10	10	70(6.19)	7	2
Tylopherynx foetidus	30	0	0	30(3.54)	3**	1
Xiphenema radicicola	10	30	0	40(3.54)	4	5
Total (%)	530 (46.90)	240(21.24)	360931.86)	1130		

F= Frequency, *Nematodes within c-p value 1 and **nematodes above c-p value 1 but not obligate herbivores, MI=0.26, PPI=0.21.

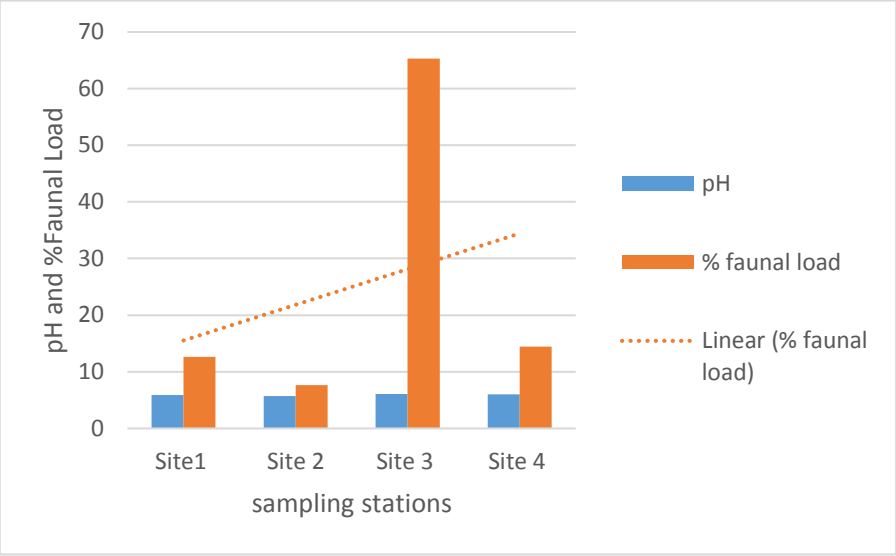

Figure 3. Relationship between pH and nematode faunal load in the study.

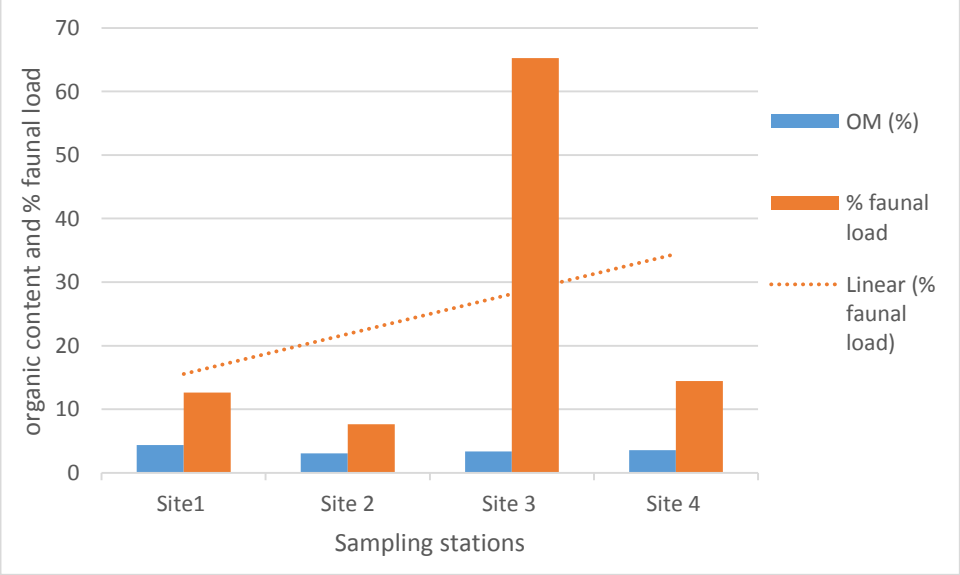

Figure 4. Relationship between Organic matter and faunal load.

assemblage of soil nematodes within the equatorial band and particularly the African region. This assessment is in no way a generalized assessment of the nematode community composition of the equatorial Uganda as only a small but unique segment of the Ugandan topology was covered and the limited time of the survey imposes a limitation. However, it is a schematics of what the nematode community of equatorial Uganda presents. Soil disturbances (tillage, synthetic inputs, organic enrichment, etc.) influenced nematode communities. The nematode assemblage of the Makerere Hill comprised a rich assay of fast-growing, r-strategist bacterivores that, over time, transform to a more diverse community including slower-growing higher c-p (2 and 3) value bacterivores and fungivores. Ultimately, these basal community populations are succeeded by higher c-p (4 and 5) omnivore and carnivore nematodes, once the level of disturbance is minimized or eliminated (Yeates et al., 1999; Briar et al., 2012 and Mwamba, 2016). The great diversity and abundance of nematodes in the various sampling sites

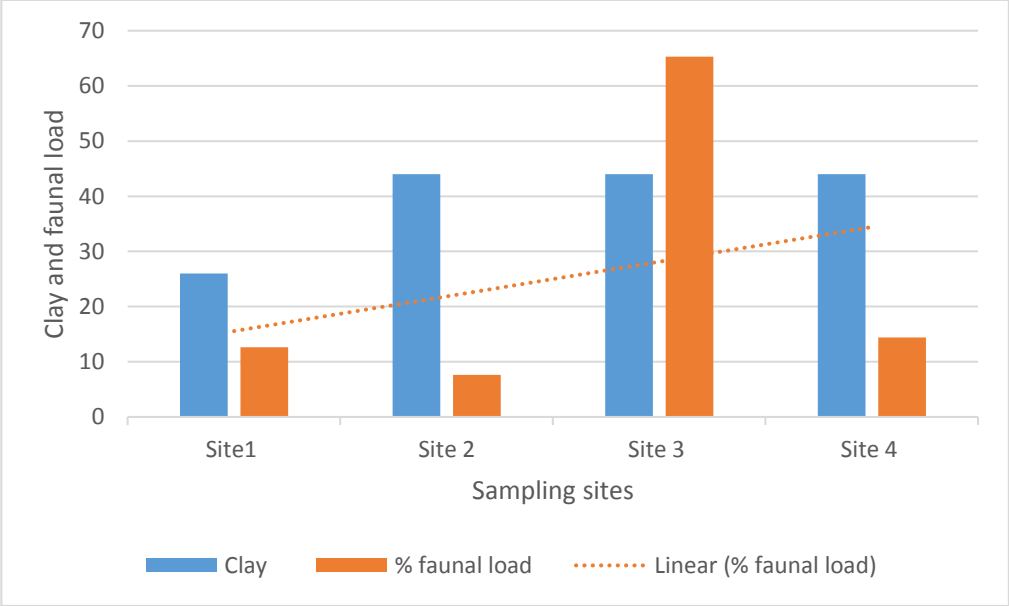

Figure 5. Relationship between clay and faunal load in the study.

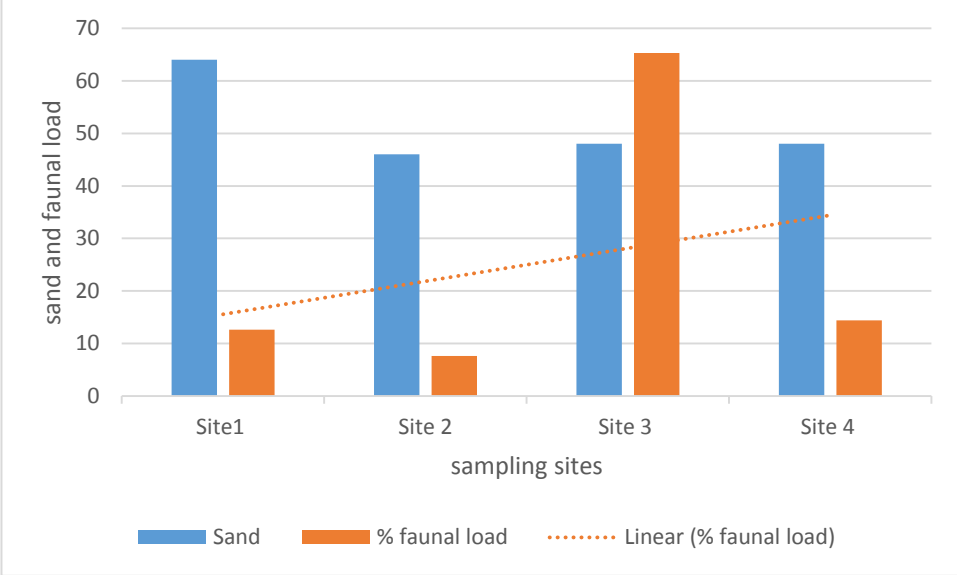

Figure 6. Relationship between sand content and faunal load in the study.

depicts a responsive ecosystem in relation to biotic and abiotic conditions. The vertical variation in the studied sites depicted an ecosystem with complex trophic cycles majorly due to continuous organic enrichment. In the study the bactriovores and fungivores were not restricted to the top soil which indicated presence of organic matter beyond the 0-5 cm stratum. It is viewed in that such a scenario could be due to anthropogenic influence that incorporates organic matter beyond the top soil. There was top-down abundance of nematodes, although, majority of the deep soil occurrences were obligates. The population of the lower c-p nematodes (c-p 1-2; colonizers) was relatively higher than those in the higher c-p (c-p 4 and 5; persisters). This suggested a trophic balance for sustainability of the food web in the ecosystem. The study agrees with inferences by

(Bongers et al. 1991, 1995; Bongers and Bongers, 1998; Berkelmans et al., 2003) that if an assemblage is exposed to pollution, colonisers are more tolerant than persisters. If *k*-strategists disappear their resources will then serve as food for more tolerant species, resulting in increase of the number of colonisers under disturbed conditions.

Conclusion

The Makerere hill ecosystem accommodates a sustainable nematode faunal population that exhibits dynamism in nematode population structure due to the various extraneous influences including, vegetation, enrichment pathways, elevation, topography and anthropogenic activities. The study documents some of the characteristics of the ecosystem that modify the organismal morphology, especially; the nematode fauna community composition in relation to disturbances. The nematode meiofaunal idiosyncrasies in the study; the maturity index, abundance, species richness and response to physicochemical patterns are indices of soil health status and can be included in future environmental evaluations in Uganda. In this study it has been established that the Makerere ecosystem is prone to disturbances that modify the meiofaunal structure and could be used to predict the health status of the environment in future. The most influential physic-chemical parameter encountered in the study was the organic content (OM) which influenced and sustained the functional characteristics of the nematodes community. The Makerere hill ecosystem is stable and composed of divergent habitats with peculiar ecomorphological characteristics which could be utilized as a reference in future nematode faunal analyses studies in Uganda.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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